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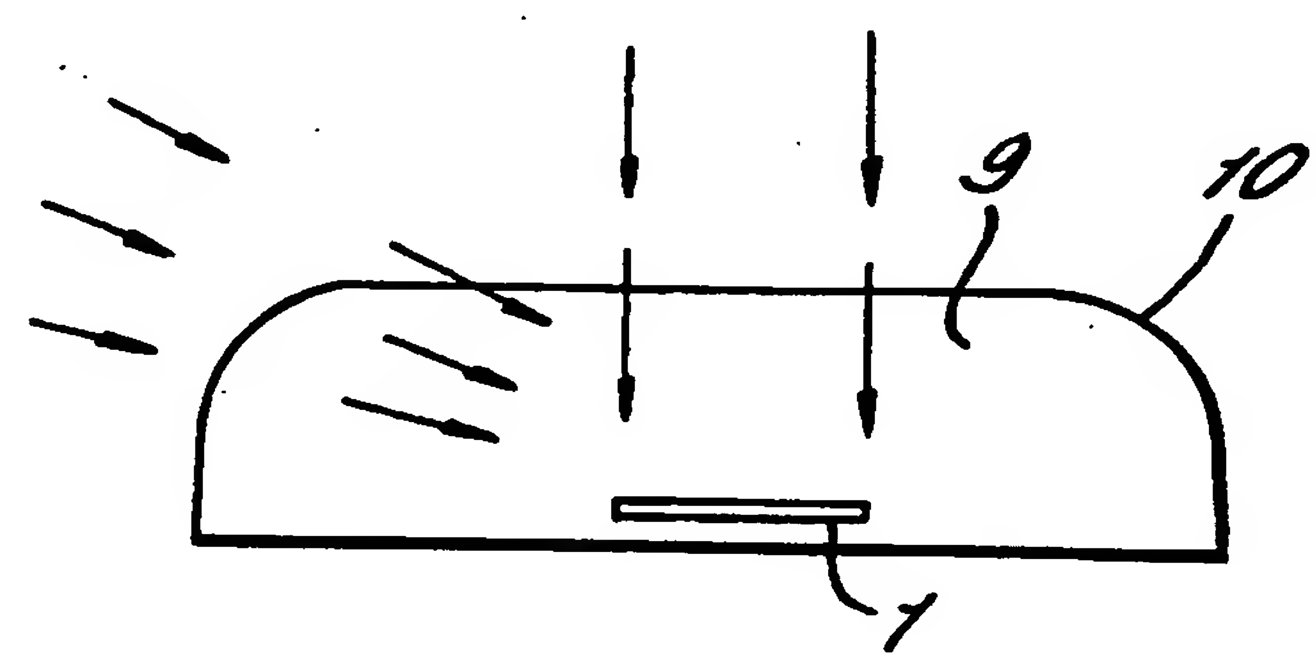
(54) Radiation detector

(57) An encapsulant 9 for a photosensitive cell 1 contains a pigment to equalize the response of the cell to visible radiation. The encapsulant may form a lens 10 or be Fresnel lens shaped to provide a substantially uniform polar response. In one embodiment a silicon solar cell intended for use in horticulture and agriculture has a peak response towards the red end of the spectrum and may be encapsulated in a resin containing a cyan pigment. A layer of resin containing an opaque white pigment may be applied on the back face of the cell. Also disclosed is a mounting arrangement utilizing an extension of the encapsulation material.

FIG. 3.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1.

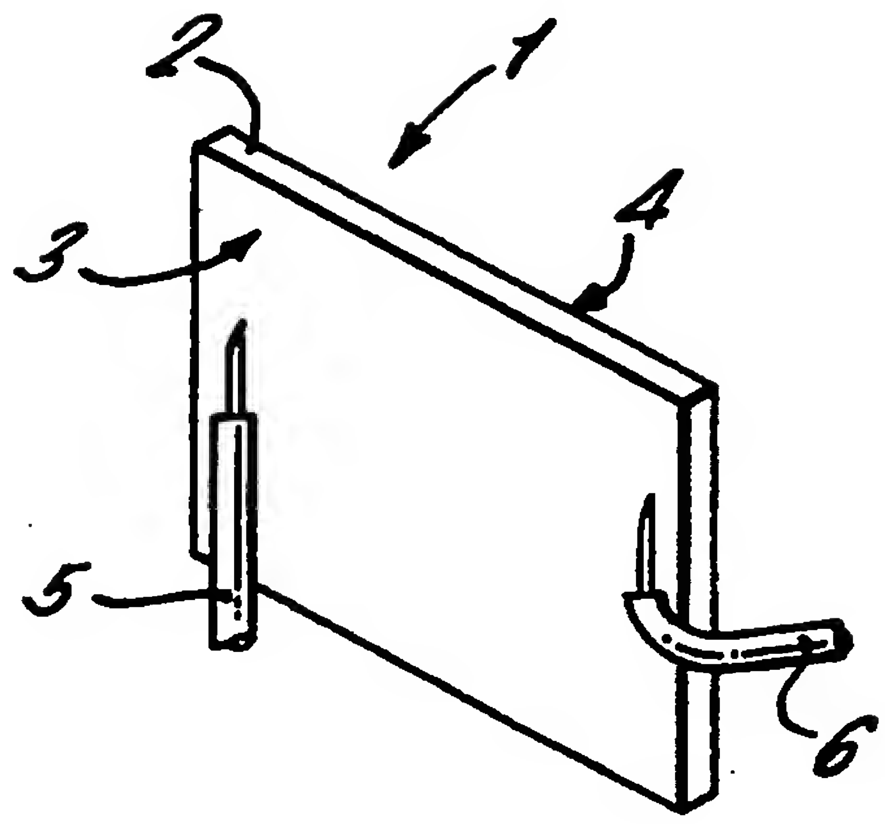


FIG. 2.

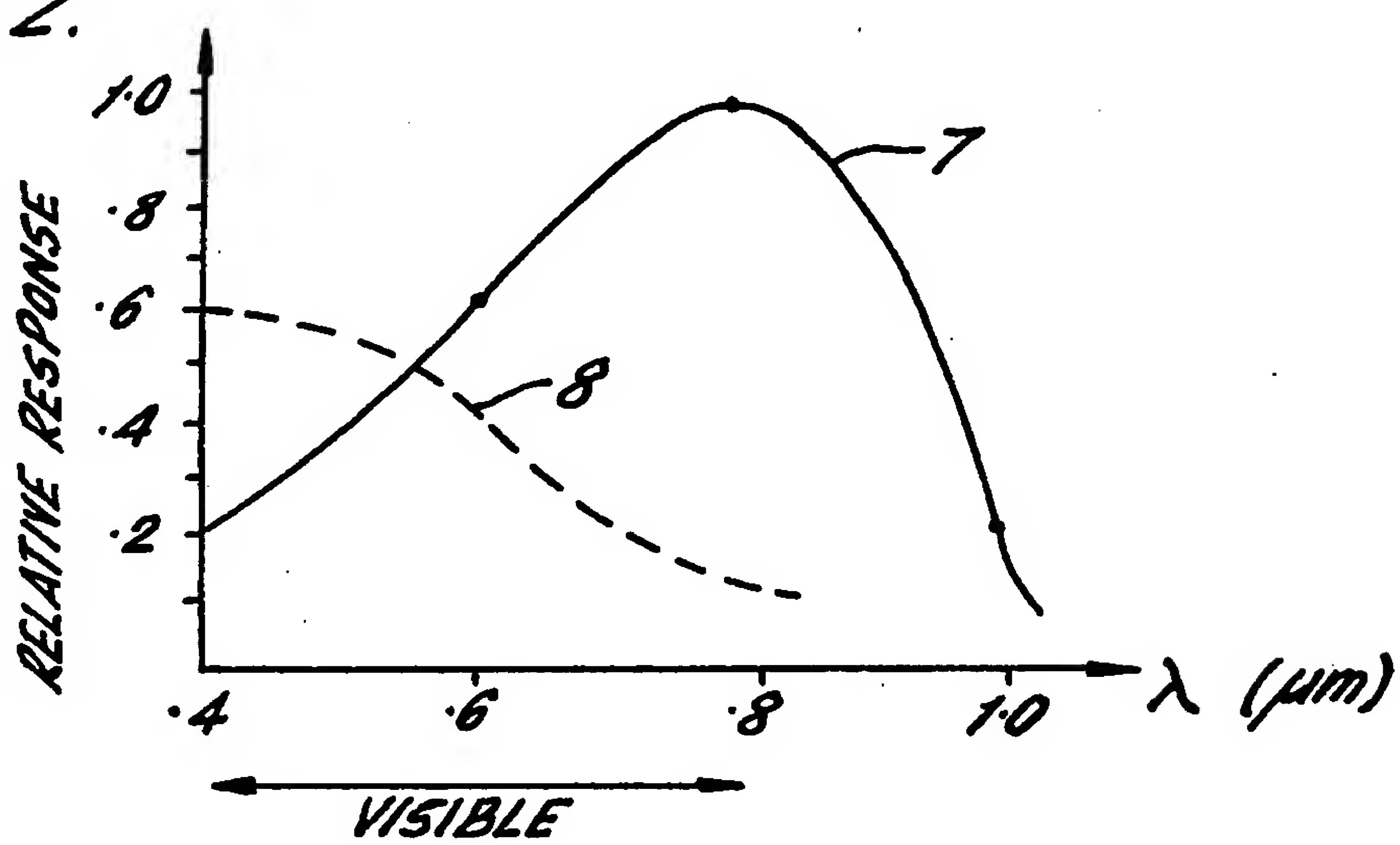


FIG. 3.

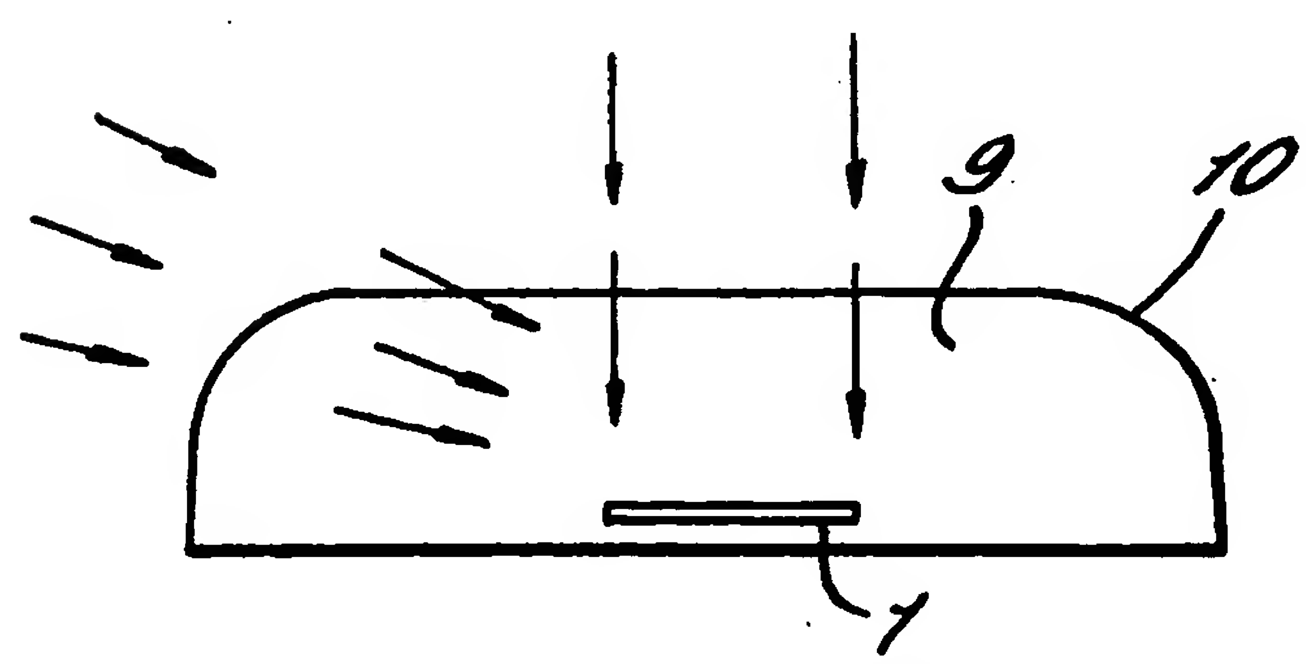


FIG. 4.

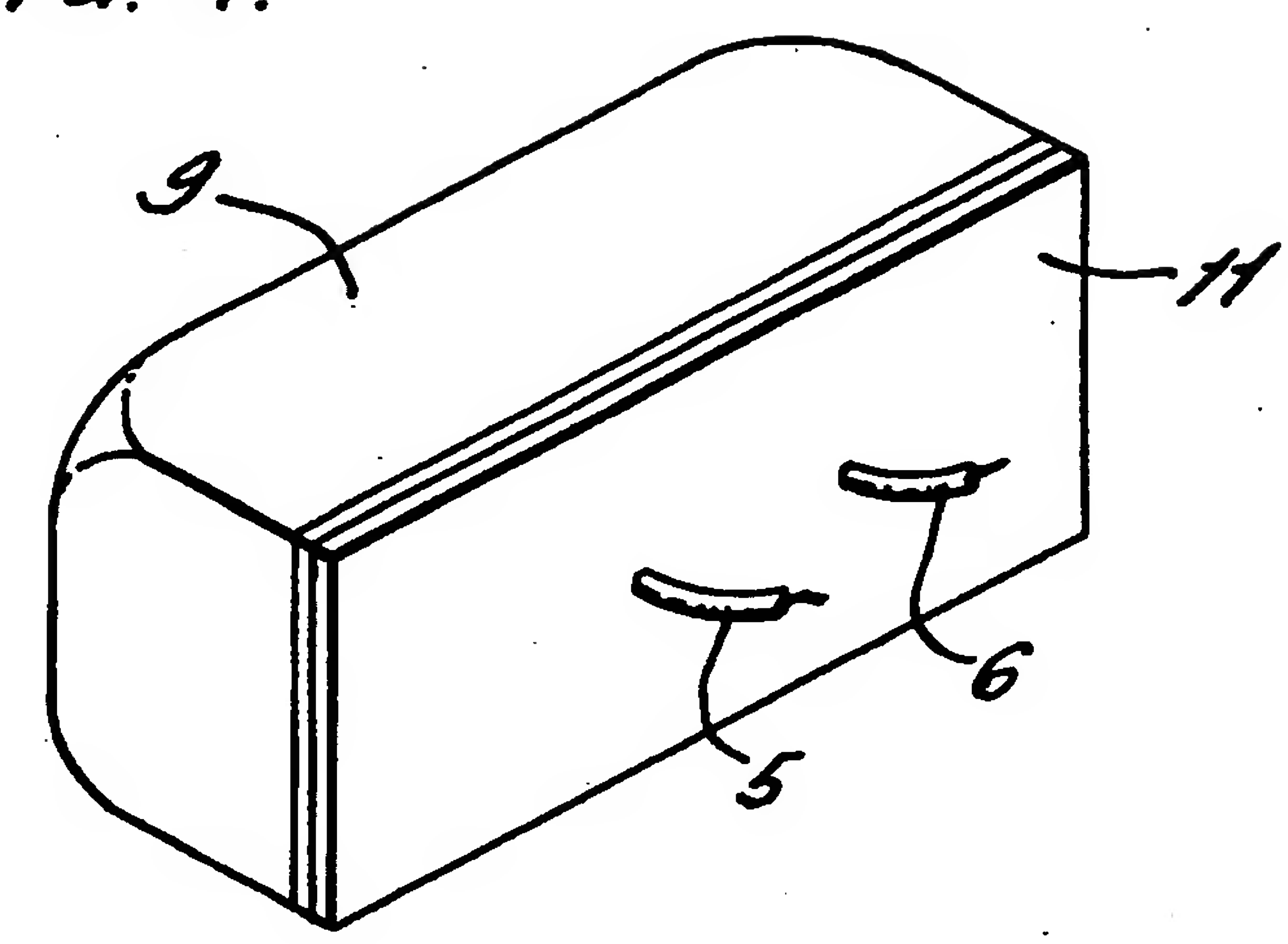
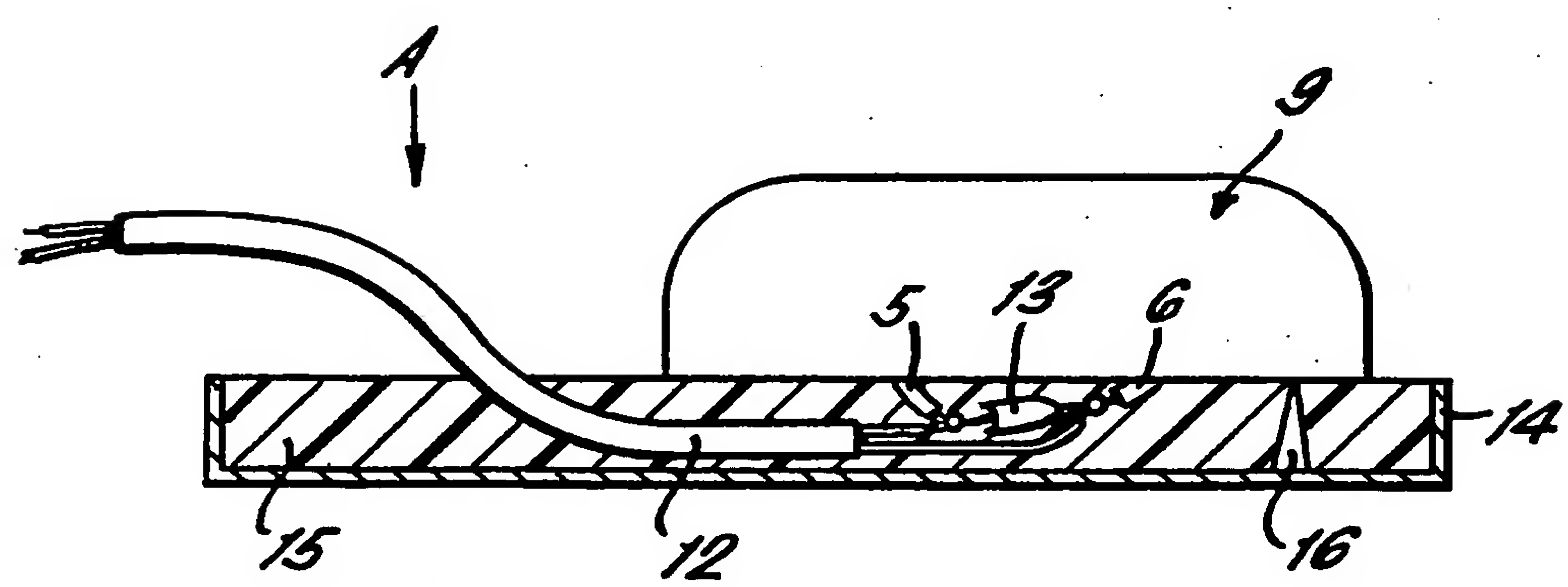


FIG. 5.



SPECIFICATION
Radiation detector

This invention relates to radiation detectors and in particular to photoresponsive sensors which are operable in response to light in the visible spectrum. A sensor according to the present invention is particularly intended for use in horticulture and agriculture.

The general object of the invention is to provide an improved sensor which has a desired spectral response and in particular a spectral response which is generally uniform in the visible region and is preferably limited to the visible region and the near infra-red region.

Another object of the invention is to provide a sensor which is generally robust and versatile.

Another object of the invention is to provide a sensor which has a substantially uniform polar response over a substantial solid angle and particularly over a hemispherical field of view.

Not all the foregoing objects need be fulfilled in every embodiment of the invention but it is a further object of the invention to provide a sensor which is convenient to manufacture and which has the advantages aforementioned. There are currently available various devices for sensing radiation levels and intended for use in glass houses or open fields. The devices normally used hitherto depend on thermoelectric effects and tend to be unwieldy, fragile and tend to produce an output which is too low unless expensive high performance amplifiers are used in conjunction with them. Moreover, their response outside the region is often undefined, the lack of definition of the response outside the visible region being often a considerable disadvantage if the device is to be used in greenhouses.

Although the present invention is not limited to the specific example described hereinafter, in which follows there is a description of a small, robust sensor which has a well defined response, in particular limited substantially to the visible region, capable of producing an output large enough to make high performance amplifiers unnecessary in any but exceptional circumstances. It has a low output impedance and accordingly may be used with long lines coupling the device to control equipment.

In the accompanying drawings:

Figure 1 is a diagrammatic view of a photovoltaic cell;

Figure 2 is a graph illustrating the response of a cell and a filter for it;

Figure 3 is a diagram illustrating the disposition of the cell in an encapsulant;

Figure 4 is a simplified rear view of an encapsulated sensor; and

Figure 5 illustrates the assembly of the sensor.

As mentioned hereinbefore, one object of the present invention is the provision of a sensor which provides an adequate output enabling the sensor to be used in horticulture and agriculture without the aid of high performance amplifiers. Figure 1 illustrates one example of a cell which may be used for this purpose. In this example, the sensor 1 comprises a silicon wafer 2 having an active side 3, a dead side 4 and leads 5 and 6 connected to the active side. Such a photovoltaic cell, of lateral dimensions 10mm square, may have an output which is approximately one thousand times the power output of a thermoelectric detector in the form of a wafer measuring 200mm by 20mm.

Figure 2 is a graph of relative response, normalised to the peak response, against wavelength of incident light. The curve 7 illustrates the response of a cell alone. The response has a peak at approximately 0.8 micrometers. The response falls rapidly in the near infra-red region (0.8 to 1.0 micrometers) and falls, though less rapidly, towards the blue end of the visible spectrum. The response of such a cell is not satisfactory alone and it is accordingly desirable to employ a filter which tends to equalise the response of the cell in the visible spectrum. For the particular cell chosen, a suitable filter is a cyan filter of which a typical response is illustrated by the curve 8. Although the filter attenuates the response of the cell, particularly towards the red end of the spectrum, the power output of the cell is great enough to tolerate the attenuation.

Of course, for cells with somewhat different response curves the filter characteristics must be chosen accordingly.

In order to render the sensor robust for use in the conditions above-mentioned, it is preferred to encapsulate the cell. As will be described later, the encapsulant may be a suitable polyester resin. However, one aspect of the present invention is the constitution of the filter by the encapsulant, and in particular by a dispersal of a suitable pigment throughout the encapsulant. A further aspect of the invention is the shaping of the encapsulant so as to equalise the polar response of the cell. Figure 3 illustrates in simplified form the cell 1 disposed in the encapsulant 9 of which the profile 10 is shaped so that light normal to the cell is simply transmitted whereas light abnormal to the cell is concentrated. The shaping of the profile is not critical, if the variation of more than about 10 per cent in the polar response of the sensor can be tolerated, it is found in practice that the polar response can be uniform up to a hemispherical field of view. If a substantially uniform polar response over a full spherical field of view is required, two sensors arranged as shown in Figure 3 can be mounted back-to-back.

One benefit of providing the filter in the form of pigment dispersed through the body of the encapsulant, which provides the action of a lens, is that the output of the device is a function of the light falling on the whole surface of the encapsulant. Small dirt particles or small shadows thrown by structural members of a building will not significantly affect the output of the cell.

If a polar response which is uniform to a tolerance of less than 10 per cent is required, it may be necessary to shape the encapsulant in the form of a Fresnel lens. In many circumstances the

form shown in Figure 3, that is to say generally rectangular with rounded margins, is adequate.

It is preferable to provide on the dead side (4) of the cell an opaque backing. Figure 4 illustrates the encapsulant 9 which on the surface adjacent the dead side of the cell carries an opaque white backing 11, the leads 5 and 6 extending through this backing.

A preferred method of making the sensor is as follows.

A cavity is prepared in the desired form of the encapsulant. Clear polyester resin is doped with the appropriate pigment and the cavity is loaded up to the level at which the cell is to be sited. The resin may, of course, be inserted in several stages, the doses of resin inserted at each stage having a different concentration of pigment.

It is normally advisable to allow the initial charge of resin to harden before the cell is disposed on it, because the resin usually shrinks considerably as it cures. The cell may be coated with a silicone grease to accommodate any additional movement of the resin and again be placed on top of the partially formed encapsulant. A small charge of pigment doped resin may now be run into the cavity to fill any cavities remaining at the sides of the cell. When this charge of resin has cured, a thin layer of resin doped with white pigment may be run over the top, sufficient to cover the cell. When this final charge of resin is hardened, the block of encapsulant may be removed; it has the appearance shown in Figure 4.

It is preferred to connect a resistor between the output leads 5 and 6 so as to provide an output voltage, across the resistor, proportional to the incident light. It is preferable to choose the resistor such that the output of the sensor is in the region of one volt per watt per square meter. The sensor may be calibrated against a standard, the resistor being selected accordingly.

When the device has been calibrated, a length of twin output cable 12 is connected to the output leads and thereby across the calibration resistor 13. The assembly is placed in a shallow tray 14, as shown in Figure 5. Resin 15 doped with opaque pigment may then be run into the tray, the sensor being temporarily supported by means of supports 16.

The sensor is now complete except for a means of mounting. This may be effected by drilling through the resin and the tray in the region of the arrow A. An alternative is to set bolts into the encapsulant 9 before it is set and to pass them through the tray during final assembly. However as a practical matter the former method is preferred.

CLAIMS

1. A photoresponsive sensor comprising a sensing element and a filter which is constituted by an encapsulant which provides at least partial equalisation of the response of the element to visible light.

2. A photoresponsive sensor of which the response is limited to a range substantially corresponding to the visible spectrum, the sensor comprising a sensing element which has a spectral response exhibiting a peak at or near the red end of the visible spectrum, and a filter, constituted by an encapsulant of the cell and providing at least partial equalisation of the response of the element to visible light.

3. A sensor according to claim 1 or claim 2 in which the filter comprises a dispersion of pigment in the encapsulant.

4. A sensor according to any foregoing claim in which the encapsulation has the form of a lens.

5. A sensor according to claim 4 in which the shape of the encapsulation is to provide a generally uniform polar response to light over a hemispherical field of view.

6. A sensor according to claim 5 in which the encapsulation has the form of a Fresnel lens.

7. A method of making a photoresponsive sensor comprising partially filling a cavity with a resin, the cavity providing a matrix for the form of a lens, disposing a wafer constituting a photo voltaic cell on the surface of the encapsulant in the cavity, and filling the remainder of the cavity with resin including an opaque pigment.

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